understanding their role in stereopsis is that the *B*+ and *B*– channels have different receptive field shapes. The receptive field of a visual neuron describes the pattern of its response to light, and receptive fields of visual neurons typically have alternating excitatory (response increased by light) and inhibitory (response decreased by light) sub-regions, with a particular phase of alternation.

Figure 3 illustrates how in principle two neurons whose receptive fields have 'even-symmetric'and 'odd-symmetric' phases are able to capture the disparity of a simple bar positioned in depth, via their respective responses to the sum and difference signals from the two stereo-halves. The *B*+ and *B*– neurons are shown to respond to the already-summed and already-differenced images, but in practice both neurons would respond to each stereo-half and their responses would be summed and differenced, but the result is the same and is shown the other way round for convenience. What the figure demonstrates is that the responses of an even-symmetric neuron to the sum, and an odd-symmetric neuron to the difference of the two stereo-halves, are stronger to the disparate bar compared to the bar with zero disparity. Hence a neuron that combines the *B*+ and *B*– responses is selective to disparity.

Why this arrangement? Li and Atick [2] argue that there is a two-fold advantage to basing stereopsis on a mechanism that sums and differences the two eyes' signals. Because the left and right images of the stereo-pair in Figure 1 are very similar, in other words highly correlated, there is a lot of redundancy in the responses of the visual neurons that encode them. One way to reduce the redundancy is to convert the responses into sums and differences, as these are uncorrelated. A similar process occurs with colour vision. There are three receptors termed 'cones' in the eye that are active in daylight vision. They are differentially sensitive to short (*S*), medium (*M*) and long (*L*) wavelengths of light. Nevertheless, their responses to natural scenes are very similar, that is, they are highly correlated. By taking the sum of the cone signals to produce a luminance-sensitive channel, and the differences between cone signals to produce colour-sensitive channels, the visual system 'decorrelates' the cone signals. The result is improved efficiency of information transmission along the visual pathway and the means to distinguish luminance (or brightness) from colour [7].

The other advantage of having *B*+ and *B*– channels is precisely what May *et al.* [5] have revealed in their study: the ability of the visual system to independently adjust the gains, or response strengths, of the two channels. This enables vision to compensate for the relatively weak *B*– signal found in images of natural scenes — compare the bottom right and bottom left images in Figure 1 — resulting also in improved coding efficiency.

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Brain Organization: Wiring Economy Works for the Large and Small

The highest-resolution test to date of the wire minimization hypothesis has found that this principle works well for brain regions with a volume just over 400 μm^3. What is the wire minimization hypothesis, and why should anyone care about it?

Charles F. Stevens

Axons and dendrites count as 'wire' and everything else in the brain is 'non-wire'. The idea is that axons and dendrites carry information over long distances and so are analogous to wire in, for example, a telephone system. Extracellular space, synapses, and glia carry information at most over short distances so they are not-wire. The wire-minimization hypothesis holds that neural components should be arranged in a way to make the volume of wire in the brain as small as possible. Wire volume should be minimized so that as much room as possible is left over for the computational elements that carry out the brain's main job. This idea, like so many others, can be traced to Cajal, but in modern times it was first used by Mitchison [1] and by Cherniak [2] about twenty years ago. According to Rivera-Alba *et al*. [3] in work published recently in *Current Biology*, the hypothesis has passed the highest-resolution test it has been put to so far.

Wire minimization has been found to explain many structural features of brain organization, such as why the cortex is divided up into distinct functional areas, why there are ocular dominance columns, why brain areas in the mammalian cortex and ganglia in the worm are arranged as they are (see references in Rivera-Alba *et al*. [3]). This principle is important, then, because it provides a simple explanation for many aspects of brain structure. Perhaps more importantly, though, when wire minimization is violated it means that some feature of brain structure is unexpected and demands a special explanation.

Although the literature contains many papers on wire minimization (64×10^3 hits in Google Scholar), almost all deal with large-scale features

such as the spatial organization of cortical areas or the arrangement of neuronal cell bodies in an entire worm. Analysis of this principle at finer resolution could not be carried out before now because we lacked enough detailed structural information. In recent years, however, a number of laboratories have dreamed of developing a complete wiring diagram of the brain — or at least of a small brain region. Chklovskii and his colleagues have shared this dream and have produced a complete structure of parts of the fruit fly brain. With this detailed information available, they have now been able to test the validity of the wire minimization principle for very small brain structures [3].

Information about the visual world is sensed by the fly's retina, and this information is first passed by photoreceptor cell axons to monopolar cells in a structure just behind the eye called the *lamina*. These lamina monopolar cells send their axons to the next visual processing stage — the medulla — and provide the fly with almost everything it needs to know about its visual world. 'Almost everything' because each unit of the fly's eye contains eight photoreceptor cells, six of which relay information to lamina cells and two of which provide visual information directly to the medulla.

Cell bodies of the lamina monopolar cells and of other lamina cells involved in the information processing (amacrine, glia, and some other cell types) are collected in the lamina cortex (a region just behind the retina) and the communications between photoreceptor axons and lamina cells occur in a region of neuropile subadjacent to the lamina cortex. This neuropil is complex, but very orderly. It is divided up into about 800 repeated units called *optic cartridges*, one for each pixel in the fly's image of the world. These cartridges are identical, are arranged in a hexagonal lattice, and each has something over 400 synapses, about 1 per μm^3, a synaptic density the same as that typically found in mammalian cortical neuropil.

The fact that the lamina neuropil has such an orderly structure suggests that the cartridges may conform to a minimum wire volume arrangement. To test this idea, Rivera-Alba *et al*. [3] used several approaches to determine if the placement of components indeed does minimize wire volume. In general, it is an extremely difficult problem to search through all of the possible component arrangements to find the one with minimum wire volume and then to compare this result to the actual arrangement. To make the problem manageable, Rivera-Alba *et al*. [3] exploited a symmetry in the cartridge structure: the arrangement of the largest components is nearly the same at each cross-section through the cartridge over its length. The authors kept constant the positions of these main components that are interconnected by side branches and found that the volume of the actual structure is less than that of a thousand structures whose average connectivity is the same as the real cartridge but where the actual interconnections have been replaced by random interconnections; the chances of this happening are less than about one in 10 million.

Rivera-Alba *et al*. [3] also used two other tests that permitted the main components to be moved around and again found that the actual arrangement had the minimum volume; this result is highly statistically significant (occurs by chance about one time in a hundred thousand). Furthermore, the authors examined other approaches, such as perturbing component sizes and connectivities, and again found the actual structure to have the smallest volume.

In the tests described above, Rivera-Alba *et al*. [3] assumed that the cross-sectional structure is basically uniform along the length of the cartridge, but this is not quite true. To see if the structural non-uniformity along the long axis of the cartridge is important, the authors incorporated observed differences in three longitudinal portions of the cartridge and examined each portion separately for minimum wire volume. As for the simpler computations above, the authors again found that wire minimization accounts well for the positions of the actual components.

In summary, then, this complete reconstruction of fly neuropil has been tested for conformity to the wire minimization principle, and this principle is found to explain the actual component arrangement satisfactorily. Rivera-Alba *et al*. [3] have thus discovered that the wire minimization principle operates down to the sub-microscopic level, at least in this brain region. As the complete structure of more brain regions becomes available, it should be possible — though increasingly difficult for less orderly neuropil —to learn the range of validity for this principle and to understand its exceptions.

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Neurogenesis: Premature Mitotic Entry Lets Cleavage Planes Take Off!

Mutations in the gene *microcephalin/MCPH1* result in the neurodevelopmental disease microcephaly. A recent report provides evidence that MCPH1 controls neuroprogenitor entry into mitosis via the Chk1–Cdc25b centrosome maturation pathway.

Priyanka Singh and Clemens Cabernard

Human primary microcephaly (MCPH) is an autosomal recessive disorder resulting in small but structurally normal brains and mild-to-moderate mental retardation [1]. At least seven loci, corresponding to the genes *MCPH1–7*, have been linked to